Road Rater™

Dynamic Deflections for Determining

Structural Rating

of Flexible Pavements

Highway Division
February 1979

Iowa Highway Research Board
Final Report HR-178

DISCLAIMER

FINAL REPORT

FOR

IOWA HIGHWAY RESEARCH BOARD

PROJECT HR-178

ROAD RATER™

DYNAMIC DEFLECTIONS FOR DETERMINING STRUCTURAL RATING OF FLEXIBLE PAVEMENTS

BY

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FEBRUARY, 1979

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HIGHWAY DIVISION
OFFICE OF MATERIALS
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ROAD RATER

DYNAMIC DEFLECTIONS FOR DETERMINING STRUCTURAL RATING

OF

FLEXIBLE PAVEMENTS

Summary

The Road Rater is a dynamic deflection measuring apparatus for flexible base pavements. The Road Rater replaces the Benkelman Beam which was last used by the Iowa DOT in 1977. Road Rater test results correlate reasonably well (correlation coefficient = 0.83) with Benkelman Beam test data. The basic differences between the Road Rater and Benkelman Beam are as follows:

1. The Benkelman Beam uses a static 18,000 lb. load while the Road Rater uses a dynamic 800 to 2,000 lb. loading.
2. The Road Rater tests much faster and more economically than the Benkelman Beam.
3. The Road Rater better simulates a moving truck than the Benkelman Beam.

The basic operating principle of the Road Rater is to impart a dynamic loading and measure the resultant movement of the pavement with velocity sensors. This data, when properly adjusted for temperature by use of a nomograph included in this report, can be used to determine pavement life expectancy and estimate overlay thickness required. Road

Rater testing will be conducted in the spring, when pavements are in their weakest condition, until seasonal correction factors can be developed.

The Road Rater does not have sufficient ram weight to effectively evaluate load carrying capacity of rigid pavements. All rigid pavements react similarly to Road Rater testing and generally deflect from 0.65 to 1.30 mils. Research will be contined to evaluate rigid pavements with the Road Rater, however.

The Road Rater has proven to be a reliable, trouble-free pavement evaluation machine. The deflection apparatus was originally front-mounted, but was rear-mounted during the winter of 1977-78. Since that time, van handling has greatly improved, and front suspension parts are no longer overstressed due to improper weight distribution.

Conclusions

The Road Rater provides a fast, economical, nondestructive test method to evaluate flexible pavements. Road Rater test data can be used to predict pavement life, set priorities for asphaltic concrete resurfacing, and design asphaltic concrete overlays.

Temperature and seasonal variations significantly affect Road Rater deflection readings and must be considered. A nomograph included in this report adjusts for temperature, but does not correct for seasonal effect. Road Rater testing will be conducted in the spring until seasonal correction factors can be developed.

The Road Rater has not successfully evaluated rigid pavements, but research will continue in this area.

Recommendations

Recommendations for continuing Road Rater research, evaluation and application are as follows:

1. A computer program should be established to reduce Road Rater raw data (Range and Sensor reading) to mean deflection (Mils) and/or structural rating. This computer printout would be similar to present friction testing printouts, and would greatly reduce Road Rater data reduction manpower needs and costs.

2. Seasonal variation study should continue to develop seasonal correction factors. Seasonal test roads will be studied concurrently with routine testing during 1979 to develop this relationship. All Road Rater testing will be conducted in the spring until the seasonal relationship is established.

3. An asphaltic concrete overlay design method should be established based on Road Rater deflection readings. The AASHTO Interim Guide for Design of Pavement Structures 1972 will be used as a base document for this study.

4. AASHTO Structural numbers should be compared to Road Rater Structural Ratings during 1979 on asphaltic concrete overlay projects. This analysis will enable us to refine Road Rater evaluation of flexible pavements. Roads will be tested before resurfacing and several months

after resurfacing (for curing and traffic compaction) to correlate overlay thickness with structural upgrading.

5. An inventory of all flexible pavements on the Primary System should be considered for testing with the Road Rater. This information would be valuable in estimating long-range resurfacing needs.

Introduction

The deflection of a flexible pavement is a good indication of the load carrying capacity of that road. The life expectancy of the pavement is dependent on the deflection and the number of times it is deflected. To measure pavement deflection under a load, the Benkelman Beam was developed. The Benkelman Beam became a widely used standard test for deflection of a flexible pavement under a static load.

To more closely simulate a rolling truck tire, methods of dynamic deflection tests were sought, including falling bodies, the Dynaflect and the the Road Rater.

Selection of a Test System

A meeting was held November 10, 1975, in the Office of Materials Laboratory for the purpose of deciding which dynamic deflection measurement device to purchase, the Dynaflect or Road Rater.

A number of state highway departments and one private testing firm had been contacted prior to the meeting in order to accumulate data on the Road Rater and Dynaflect. Most agencies had experience with either the Dynaflect or Road Rater, but not both. However, the Pennsylvania Department of Transportation had used both and strongly recommended the Road Rater. The Kentucky Department of Transportation and Pavement Testing Corporation used the Road Rater, but have limited experience with the Dynaflect. Both of these agencies recommended the Road Rater. The other agency using the Road Rater was the Maryland Department of Transportation. The states contacted using the Dynaflect were South Dakota, Nebraska, North Dakota and Utah. These states were satisfied with the Dynaflect, but had no experience with the Road Rater.

Iowa personnel traveled to Nebraska to observe the operation of a Dynaflect. Maintenance operation and application of test data were discussed with Nebraska personnel. Acutal testing was then observed. The testing time was found to be about 1 minute and 35 seconds plus driving time between tests.

From the letters and discussion with these agencies and from brochures from the maufacturers of the Dynaflect and Road Rater many differences were observed. These differences were discussed at length at the meeting. Some of the differences are noted in the table on the next page.

	Dynaflect	Road Rater
Cost & Equipment	$14,050 including training; trailer unit; one meter; 5 sensors	$25,000 Van; 4 meters and 4 sensors
Changing Dynamic Frequency	May be changed, but with much difficulty	Changed by rotary switch
Changing Static Load	May be changed, but with some difficulty	Changed by hydraulic valve
Changing Dynamic Load	Very difficult to do	Changed by a variable resistor
Time of Test:		
Short Interval	1 minute	Approx. 1 minute
Long Interval	2 3/4 minute	Approx. 2 min. $\pm \frac{1}{2}$
Sensor Calibration	One or twice each day	Factory calibrated

Maintenance costs are unknown. Both correlate to the Benkelman Beam and are repeatable.

It was noted that the Road Rater had provision for varying the load. This versatility provided potential for investigating the effects of load and frequency changes on pavement. Also, the Road Rater can distinguish between roads of better quality where the Dynaflect cannot. The reason for this is that the greater load used by the Road Rater will cause larger deflections. The ability to change the frequency will enable the Road Rater to get accurate readings on roads with low resonant frequencies.

The Dynaflect is a trailer unit and would have been towed by a van used for Road Roughness and CHLOE Profilometer tests.

A conflict could be possible in the event two of these tests were needed at the same time. The Road Rater which comes with its own vehicle would eliminate this problem. However, at times when the Road Rater is not being used the van may be used for other activities.

Although there was a substantial difference in cost of the two test machines, it was felt that the greater cost of the Road Rater was warranted. The Road Rater is slightly faster, much more versatile and includes more equipment.

The decision was made to purchase the Road Rater.

Road Rater

The Road Rater, produced by Foundation Mechanics Division of Wylie Laboratories, is an electronically controlled hydraulically powered unit mounted in the rear of a van type vehicle (Figure 1 and 2). A servo valve allows a pulsating flow of hydraulic fluid that imparts a movement into a large mass mounted in the center of the test mechanism. The resultant movement of this mass produces a force that is applied to the pavement. Through elevating cylinders,part of the weight of the vehicle is also utilized. The dynamic loading varies from 800 to 2,000 lbs. The force being applied to the pavement is monitored by a velocity sensor attached to the top of the two-way hydraulic ram that produces the movement. The

Figure 1. Road Rater Van

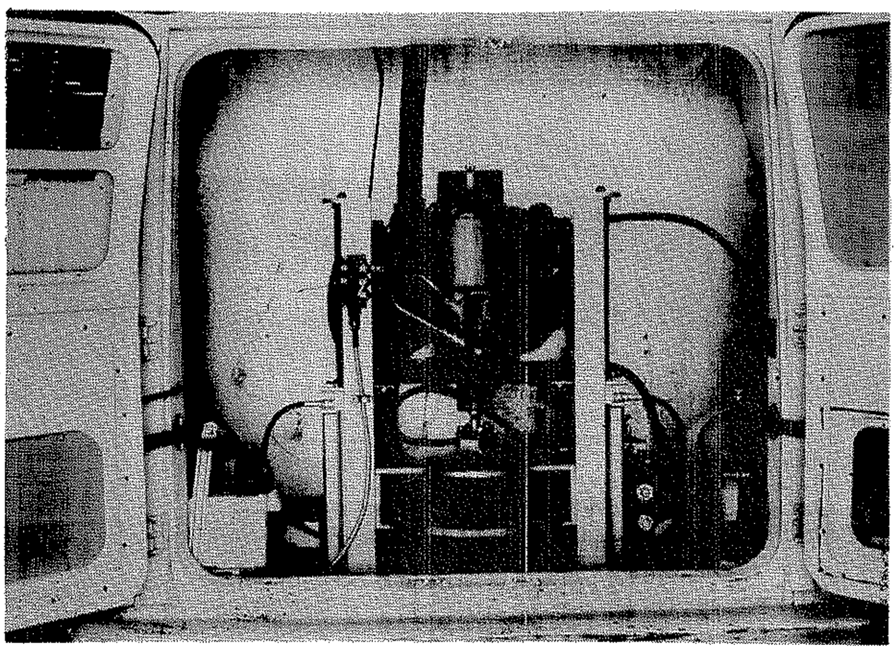


Figure 2. Road Rater Mechanism, Rear View

resultant movement of the roadway surface is measured by identical velocity sensors that are lowered to the surface (Figure 3). An electronic console (Figure 4) containing the controls to regulate the frequency (10, 20, 25, 30 & 40 hz) of loading is located inside the vehicle, next to the driver. The resultant movement as measured by the roadway velocity sensors is displayed on meters contained in the console. The hydraulic and electrical power is supplied by an auxiliary engine mounted in the rear of the van.

For normal operations the Road Rater crew consists of four people: A driver-operator, recorder and two drivers of sign-carrying safety vehicles. For high traffic freeways, an additional driver and vehicle with a sequential flashing arrow are required.

The Road Rater requires only 20 to 30 seconds per test. Far more projects can be tested with the Road Rater than is possible with the Benkelman Beam. The Road Rater mechanism has had only minor problems. An air pressure tank and a pressure gauge are carried in the vehicle for daily checks of the air cushions on the test mechanism. Some adjustment of hydraulic pressure has been required. The replacement oil filters for the hydraulic system have shorter service life than the original Lentz filter and frequent replacement is necessary.

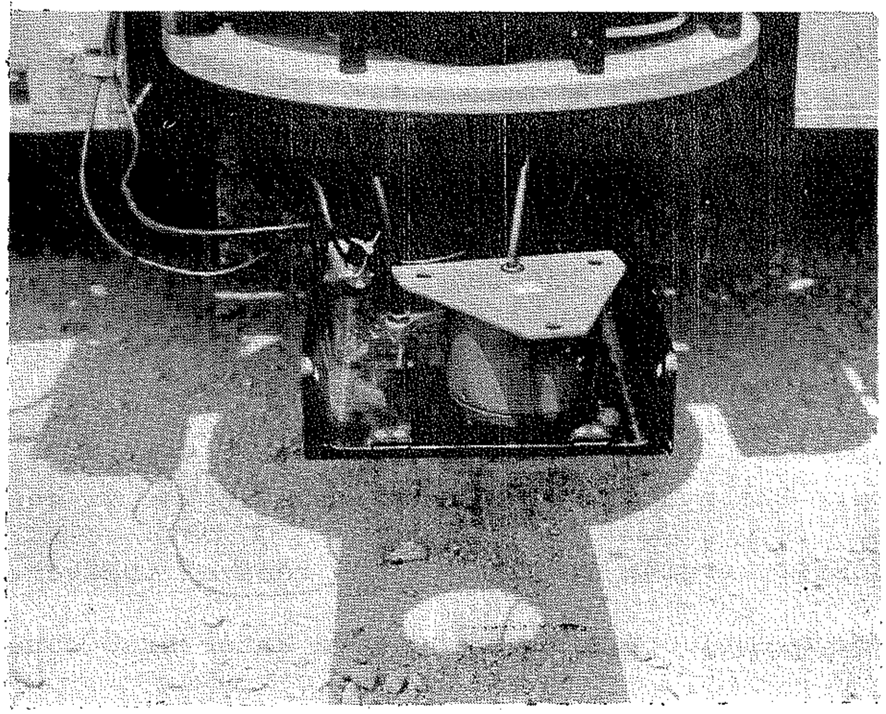


Figure 3. Velocity Sensor Lowered to the Surface

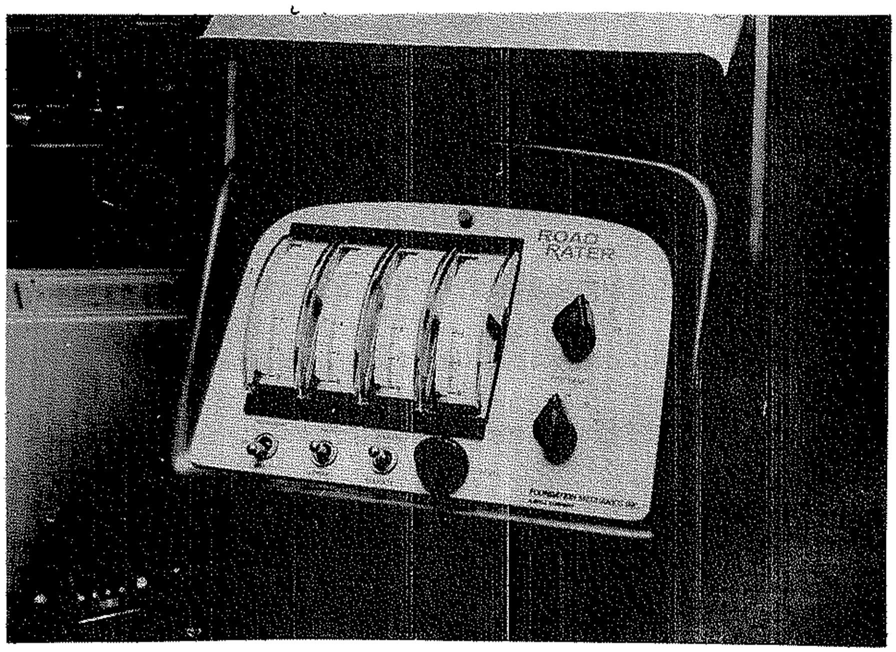


Figure 4. The Console with Controls and Display Meters

The Road Rater test apparatus was originally front-mounted on a Ford Van. (Figure 5)

Figure 5. Road Rater as Originally Front Mounted

After the 1976 season, it was discovered that the excessive weight had distorted the front suspension. Testing was suspended during March and April of 1977. Stronger springs were installed for the 1977 season, but the problem returned in November. Even when properly aligned, the handling qualities of the vehicle were poor because of improper weight distribution. After the 1977 season, the Road Rater was returned to the Foundation Mechanics Factory in California where the test mechanism was moved from the front to the rear of the van. This solved the vehicle suspension and handling problems.

Manpower restrictions limited Road Rater testing in some areas of potential use. Routine testing was conducted May through August, 1977 and June and July, 1978. Seasonal variation testing was conducted May through November, 1977 and April through September, 1978. Temperature variation tests were conducted through November, 1977.

Correlation of the Road Rater and Benkelman Beam

All of the Iowa DOT's previous pavement deflection data are available from Benkelman Beam studies which have proven to be reliable. If the Road Rater would also yeild reliable data in regard to structural adequacy, there should be a good correlation.

The pavement deflection testing program includes special requests by either the Soils Design Engineer, the Materials Bituminous Engineer, the Construction Bituminous Engineer or the Research Engineer. These requests are made to evaluate roads of questionable load carrying capacity, strength gain from resurfacing, experimental projects or performance of selected roadways. Roadways with a wide range of structural adequacy were selected from these requests for use in the correlation.

The Road Rater deflection value was determined in the outside wheelpath at a selected station or milepost. The Road Rater test procedure is given in Iowa Test Method No. 1009-A

(Appendix A). For this testing, the values for sensors No. 1, No. 2 and No. 3 were recorded. The Benkelman Beam deflection was determined a few minutes later at the same location. The data for this correlation was taken from ten different roadways and includes 69 individual test locations. The Benkelman Beam data was compared separately to the data from each of the three sensors of the Road Rater. The correlation coefficients were 0.83 for Sensor #1, 0.64 for Sensor #2 and 0.79 for Sensor #3. Sensor #1 is located between the contact feet that apply the load to the pavement. Sensor #2 is 12 inches from Sensor #1 and Sensor #3 is 24 inches from Sensor #1.

Multiple sensors indicate the shape of the deflection dish. Only the data from Sensor #1 was used as it yielded the best correlation coefficient. The plot of this correlation is shown in Figure 6. The conversion formulas from this correlation are:

$$RR = 0.0455\ BB + 0.54$$
$$BB = 22.0\ RR - 11.9$$

Both the Road Rater (RR) and the Benkelman Beam (BB) are expressed in thousandths of an inch (0.001") or mils. The correlation coefficient of 0.83 is not as good as desired. A similar correlation in California yielded a correlation coefficient of 0.89. The inability to obtain a better correlation may be due to comparing a dynamic test to a static test.

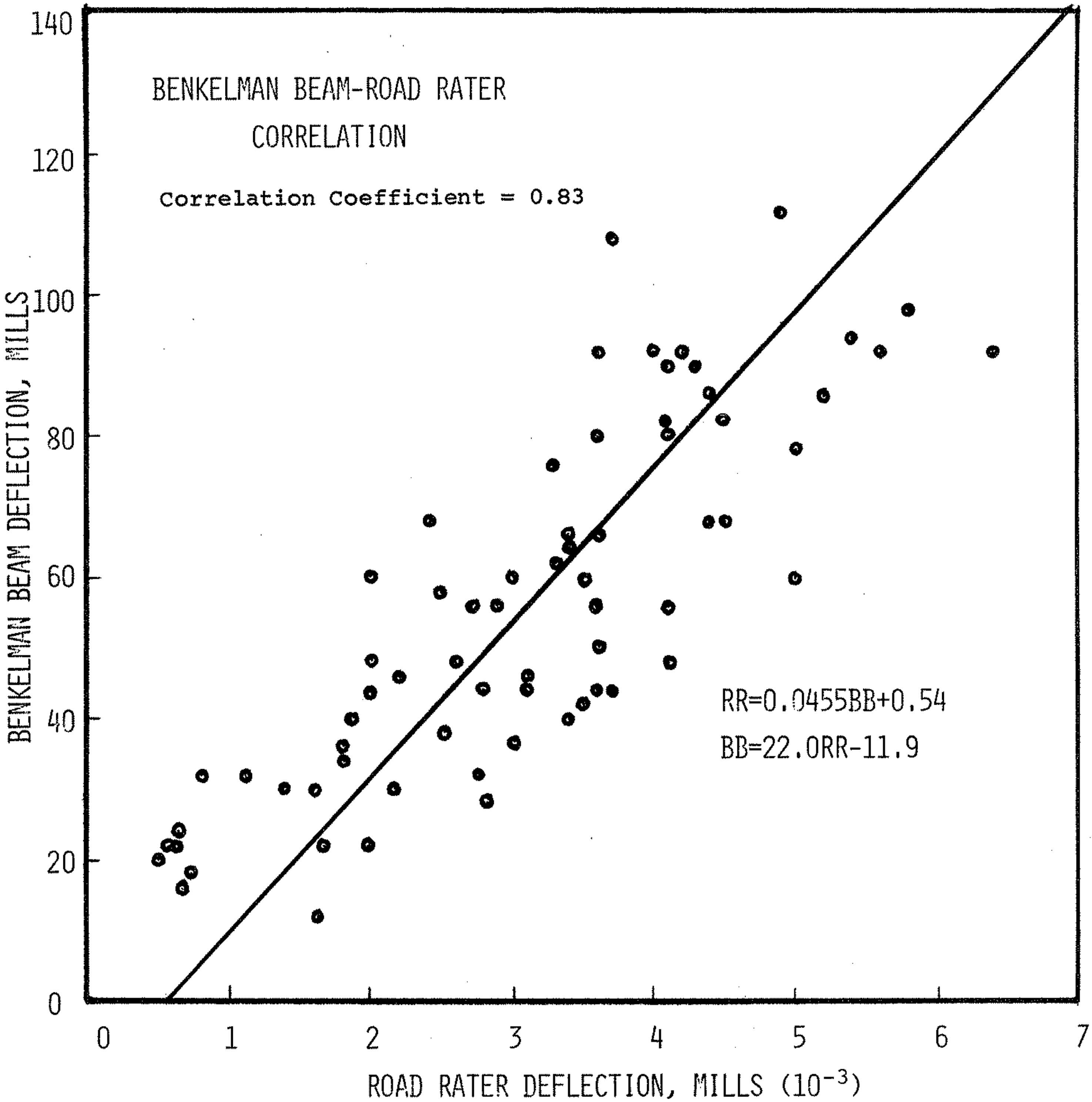


Figure 6. Correlation of The Road Rater and Benkelman Beam.

Proponents of dynamic testing claim that because traffic presents a dynamic loading that roadways should be tested dynamically. This correlation should be sufficient for comparing future Road Rater results with past Benkelman Beam studies. It also supports the reliability of the deflection data obtained by the Road Rater. Benkelman Beam data was obtained annually, but was not systematically utilized for pavement design. During 1977, only one special project was tested with the Benkelman Beam. In 1978, no Benkelman Beam tests were conducted and the Benkelman Beam test truck was sold.

Seasonal Variations

Seven projects were selected for a seasonal variation study in central, north central and southwestern Iowa. Monthly testing was scheduled from spring thaw through winter freeze-up beginning in 1977. A record drought beginning in late 1976 produced unusual subgrade conditions. Additional data will be required before a normal seasonal variation relationship can be determined. Roadways tested for seasonal variation in 1977 and 1978 were:

	Route	County	From	To
1.	Ia. 175	Hamilton	I-35	Radcliffe
*2.	Ia. 7	Webster	Calhoun Co.Line	US 169

	Route	County	From	To
3.	Ia. 4	Guthrie	Panora	Ia. 141
4.	Ia. 89	Boone	Woodward	Madrid
5.	Ia. 210	Story	Slater	US 69
6.	US 71	Cass	N. Jct. Iowa 92	Atlantic
7.	Ia. 107	Franklin	Alexander	Messervey

* Flexible Sections Only

Iowa 175 in Hamilton County was resurfaced in 1977. Iowa 89 and Iowa 210 were resurfaced in 1978 and US 71 is scheduled to be resurfaced in 1979. Although the resurfacing of these roads interrupts the seasonal variation data, they will be used to study the increase in structural rating provided by resurfacing.

The temperature adjusted average deflection of six (6) of these projects was 36% greater in the spring of 1978 than during the dry summer of 1977. The older pavements of thin cross section had a greater seasonal variation than the newer, deeper pavements. This limited data is depicted in Appendix B.

Temperature Measurements

Before the 1977 testing season, a Model R-380 AF Raytek infrared temperature gun was purchased. This had too high a scale and was not satisfactory at lower temperatures. It was exchanged for a Model R-380 RVF. Ideally, we should determine an average temperature for the pavement structure. Because of the expense and time involved in securing temperatures at various depths, it was deemed unnecessary for inventory purposes. The surface temperature measured by infrared radiation provides a practical way of adjusting for temperature variations.

Temperature Variations

Four projects were selected for temperature variation studies. Roadways tested for temperature variation in 1977 were:

	Route	County	From	To
1.	R-38	Story	Ames	Slater
2.	Ia. 210	Story	Slater	US 69
3.	S-14	Story	E-63	Nevada
4.	Ia. 175	Hamilton	I-35	Radcliffe

These roads were tested on a twice daily basis (morning and afternoon). Testing was scheduled on days when weather forecasts indicated the desired pavement temperatures would be obtained.

Bituminous pavements constructed with lower load carrying capacity exhibited a much greater variation with temperature changes than did pavements of better structural design. On one project, the mean deflection was 58% greater in the afternoon than in the morning because of temperature variation.

Road Rater Deflections and Theoretical Structural Ratings

Theoretical structural ratings were calculated, based on design thickness and type, with adjustments for deterioration caused by age and traffic. Differences in materials, construction practices, traffic history and subgrade soils make accurate determination of theoretical structural ratings very difficult.

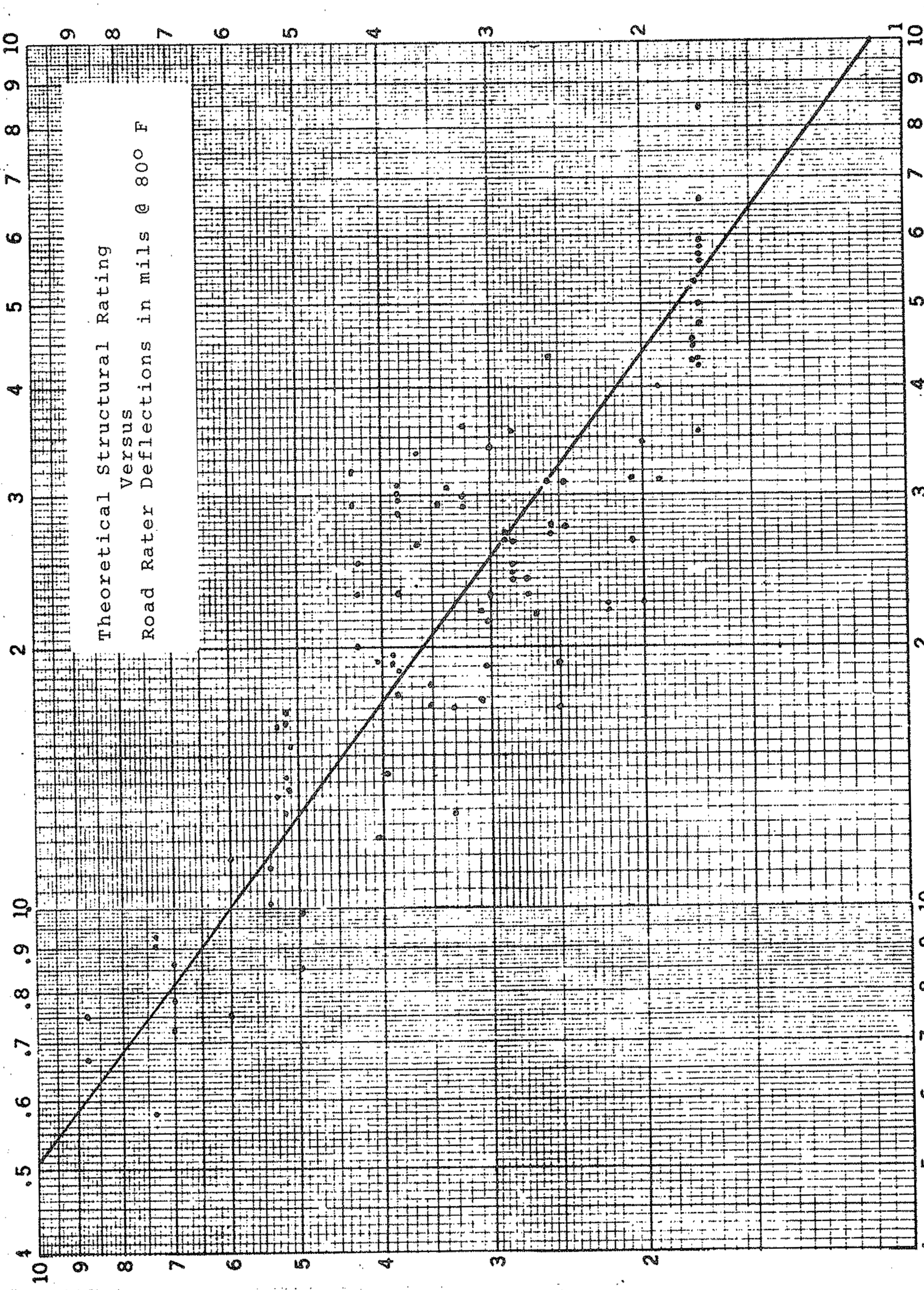
Road Rater deflections from 1977 and 1978 testing have been plotted versus theoretical structural ratings in Figure 7. This was used in relating temperature adjusted deflections to structural ratings on the nomograph (Figure 8). The Road Rater deflections are a better indication of the true "real world" structural rating than the theoretical calculated values.

Development of Nomograph

The nomograph (Figure 8) was developed to correct the mean deflection to a standard 80° F pavement surface temperature. The 80° F standard was selected since it is slightly lower than the median temperature of the summer inventory program. The nomograph is constructed to provide a greater temperature adjustment for roads with a large deflection (and therefore, a low structural rating) and less adjustment for stiffer pavements.

Example

The mean deflection for a project is 3.37 mils. Enter the right hand scale. The recorded surface temperature was 100° F on the left hand scale. Read the deflection (corrected to 80° F) on the left side of the middle scale 2.98 mils. The structural rating (right side of middle scale) is 2.65.



Theoretical Structural Rating

Figure 7 Road Rater Deflections - mils @ 80° F

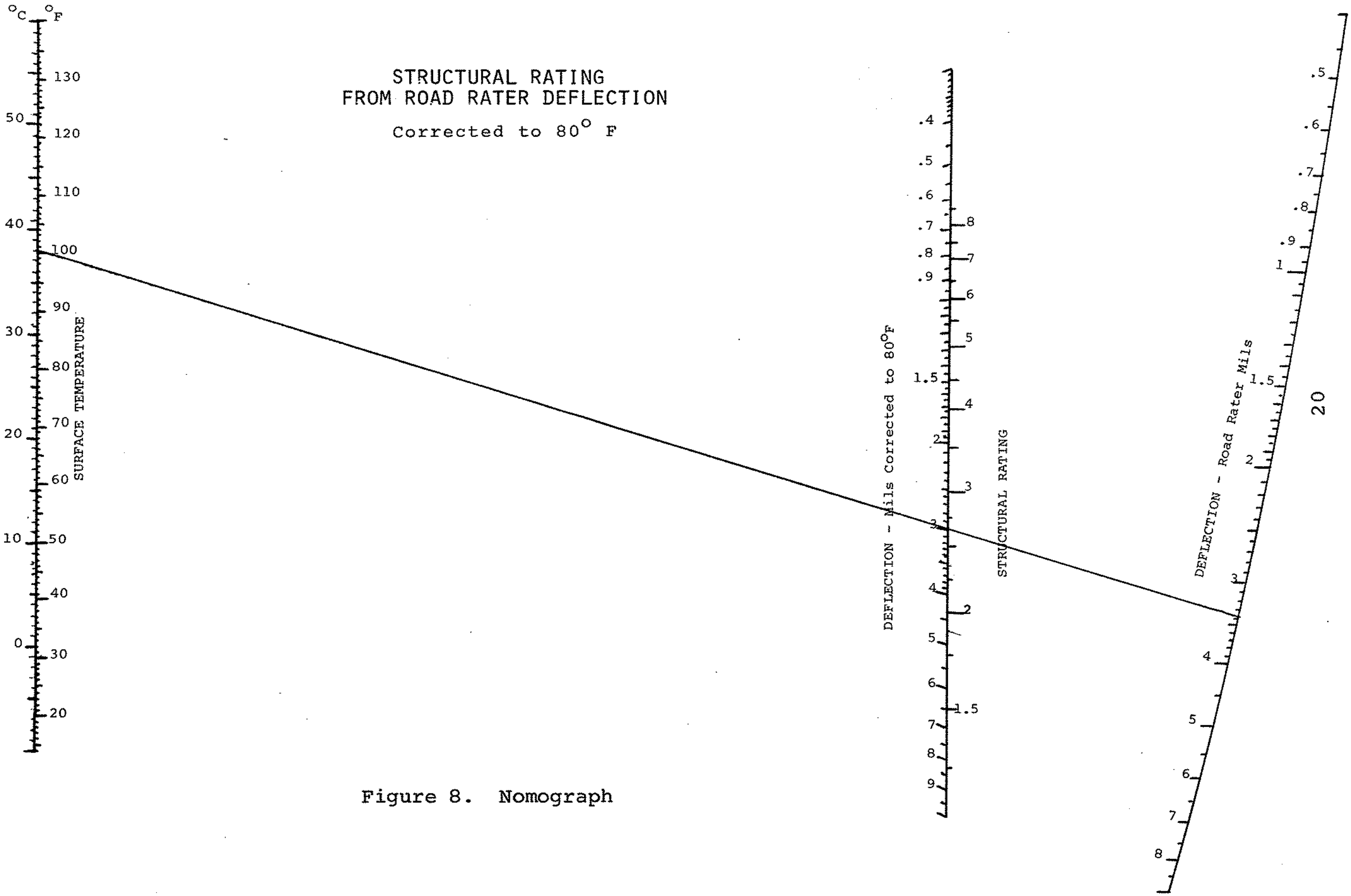


Figure 8. Nomograph

Routine Pavement Testing

One hundred twenty-one Primary and eleven Secondary roads were routinely tested in 1978 in accord with Test Method 1009-A (Appendix A).

The object of inventory testing is to establish a mean structural rating for each section of roadway. For statistical validity, a minimum of 30 readings is required for each section of roadway. On longer projects, a minimum of four (4) readings is required for each two-lane mile. Individual test locations are spaced evenly throughout the project with tests in adjacent lanes staggered. Locations are referenced from roadway mileposts. The results are reported to the Division of Planning and Programming and to the Office of Road Design for use in construction programming and design of nominal resurfacing thickness. Appendix C lists the 1978 results.

Testing for Detail Design

Detail designing of patch areas, strengthening courses and changes in nominal resurfacing thickness will require more data than provided by the routine testing outlined above. A greater frequency of testing will be required. Additional tests would be needed to isolate and define areas of different structural ratings.

Miscellaneous Testing

In accord with research proposals and Federal requests, test data was gathered for various other research. This data was reported to the requestors for their analysis and use.

Macadam Base

Test were run on Des Moines County X-31 (Research Project HR-175) and US 6 near Adel (Research Project HR-181) for Macadam research. Control or comparison sections were tested in Linn County (Macadam base), US 30 shoulders in Boone County and I-35 shoulders in Hamilton County.

Recycled Asphalt

Spring and fall tests were conducted on recycled asphalt projects built in Kossuth County in 1975 (HR-176), 1976 (HR-1008), and 1977 (HR-188). They are being tested annually.

Portland Cement Concrete Testing

"D" Crack Study

Eleven "D" cracked pavements were tested in 1977 (Table 1). Areas were tested near transverse joints (T.J.) and at mid-panel (M.P.). As expected, deflections usually were greater near the joints than at mid-panel.

Subgrade Study

Five (5) pavements with different subgrades were tested. The results are listed in Table II.

Table I

Road Rater "D" Crack Study Summary

Temp.	Stone	Year	T.J. Mean (mils)	M.P. Mean (mils)	T.J./M.P. Ratio
90°-91°	Stanzel	1975	1.0187	0.9404	1.08
84°-88°	Stanzel	1971	1.5047	0.9620	1.56
100°-102°	Stanzel	1969	1.0253	0.9357	1.10
92°-104°	Menlo	1972	1.1834	1.0826	1.09
94°	Menlo	1968	1.5913	1.2953	1.23
100°-102°	Menlo	1964	0.9419	0.8637	1.09
95°-106°	Logan	1970	0.9615	0.9303	1.03
102°	Logan	1968	1.1500	1.1405	1.01
100°	Logan	1964	0.8409	0.7438	1.13
97°-98°	Early Chapel	1975	0.9853	1.0193	0.88
93°-99°	Early Chapel	1968	0.8447	0.7764	1.09

Table II

Road Rater Subgrade Study

			Select Soil		Moisture & Density		M & D Select		Combined	
Road	Co.	Dir.	T.J.	M.P.	T.J.	M.P.	T.J.	M.P.	T.J.	M.P.
US 218	56	NB			1.38	1.06				
		SB			1.12	1.01				
		C			1.25	1.04				
US 59	83	C	0.97	0.94	0.95	0.91			0.96	0.93
US 63	7	NB	0.91	0.80						
		SB	1.05	0.83						
		C	0.97	0.81						
IA 13	57	NB	0.68	0.64						
		SB	0.77	0.67						
		C	0.73	0.65						
IA 38	70	C	1.16*	0.86*	0.94	0.88	1.05	0.95	1.02	0.92

*Only four readings.

Proposed Testing in 1979

During 1979, plans are to limit the routine testing to those flexible highways that are under consideration for resurfacing in the next two or three years.

The Iowa DOT Aeronautics Division has requested airport runway testing. This would include most of the flexible base runways on general aviation airports.

Appendix A

Method of Test for Determining Pavement Deflection Using the Road Rater

Test Method No. Iowa 1009-A
June 1977

IOWA DEPARTMENT OF TRANSPORTATION
HIGHWAY DIVISION

Office of Materials

METHOD OF TEST FOR DETERMINING PAVEMENT DEFLECTION USING THE ROAD RATER

Scope

The Road Rater is an electronically controlled, hydraulically powered unit mounted on the front of a van type vehicle. The unit inputs a dynamic force into the pavement and measures the movement of the surface using velocity sensors. This velocity is integrated to show displacement which is referred to as pavement deflection which is a measure of structural adequacy. The pavement deflection data can be used to predict the performance of the surface, the probable maintenance required, and the resurfacing needed to restore the surface to required structural capability.

Procedure

A. Apparatus

1. Road Rater (Figure 1)
2. Air Pressure Gauge
3. Temperature equipment (Raytek Infrared gun or thermocouple)
4. Safety Support Vehicles

B. Test Record Form

Original data is recorded on a data processing input form (see example on Page 4). If available the following data should be recorded:

1. The numeric designation of the county
2. The highway system: P-primary, S-secondary, I-interstate
3. The state or county route designation
4. Beginning and ending milepost on the primary system or mileage designation on the secondary system.
5. Direction of the lane being tested
6. Pavement Type: PC-Portland cement concrete, AC-Asphaltic concrete, SC-seal coat
7. Date tested: May 4, 1977 - 050477
8. Time: When testing begins based on a 24 hr. clock
9. Lab Number and Year Built
10. Observer: The person operating the Road Rater
11. Weather: Cl-cloudy, S-sunny, PC-partly cloudy, C-clear
12. History by year and structural rating
13. The location (by milepost or odometer), range (Road Rater console selection), sensor 1 (per cent of meter), sensor 2 and remarks (an identification of a complete remark shown at the bottom).
14. Remarks should include: lane designation on multilane roadways, air and surface temperatures, fixed references and unusual conditions.

C. Test Procedures

1. Determination of testing frequency

   a. A minimum of 30 individual tests shall be obtained per test section when inventorying. A minimum of 50 individual tests are needed for special evaluation of a given roadway.

      1. Under 8 miles adjust spacing to obtain a minimum of 30 tests.
      2. For test sections greater than 8 miles in length a minimum of 4 tests shall be made for each two-lane mile.
      3. Tests of adjacent lanes shall be staggered and evenly spaced to obtain a maximum representation of the roadway.

b. Testing frequency shall be as noted or as directed by the engineer for special test sections.

2. Preparation prior to testing

   a. Open overhead engine compartment vent.

   b. Check engine oil level.

   c. Start the engine and allow to run for a five minute warm-up period.

   d. Check air pressure in the two upper air springs with a good tire air pressure gauge. Add air if required to bring the spring pressure to 50±5 psi.

   e. Check air pressure in the six center air springs. This check must be made with the small valve that separates the two sets of air springs in the open position (clockwise to open). Add air as may be required to bring this pressure to 40±5 psi. Close the small valve (counter-clockwise) until finger-tight.

   f. Install the channel that holds the sensors in the recess at the base of the foot. Lock the channel in place with set screws. For normal operation, only sensor No. 1 and No. 2 will be used. Secure the electrical connections to the recepticles designated for No. 1 and No. 2.

   g. On the console (figure 2) within the vehicle place the power switch to "monitor". Hold the function switch to "elevate". Hold the movement switch in the "raise" position until the elevator cylinders are "full up" against the stops.

   h. With the unit in the "full up" condition lift the upper lock rings on the elevator cylinders and remove the two sets of mechanical locking tubes.

   i. With the power switch to "monitor" and the function switch held to "elevate", hold the movement switch to "lower" until the unit has been lowered sufficiently to elevate the van. Maintain these switch positions until no motion is evident (allow about 5 seconds).

   j. With the function switch held to "elevate" and the movement switch held to "lower", read the system hydraulic pressure on the gauge. The pressure should be 600+25 psi.

   k. Set the frequency control at 25 Hertz.

Figure 1

The Road Rater

l. Place the function switch to vibrate and set meter No. 4 to read 58 by adjusting with the "level" control.

m. Observe the reading on Meter No. 1.

n. Repeat steps g. i, l and m to check the repeatability of the setting.

o. Raise the unit to the "full up" position.

p. Stop the engine and check the level of hydraulic oil in the reservoir. Use clean "Aeroshell Fluid 4" to bring the level to between 1 and 2 inches from the top of the reservoir.

3. Testing Operation

a. With the engine running, position the Road Rater foot over the outside wheel track at the predetermined longitudinal location.

b. Place the vehicle in the "park position".

c. Lower the unit sufficiently to elevate the van, maintain the switch positions for about 5 seconds until no motion is evident.

d. With the power switch in "monitor" and the function switch in "vibrate" verify a 58 per cent reading on meter No. 4.

e. Select a range that will yield a reading between 50 and 100 on meter No. 1.

f. Record the lane, milepost, range and readings for sensor #1 and #2. Note any changes in surface type.

g. Raise the unit and proceed to the next test location.

4. After testing operation

a. When traveling between testing locations assure that the elevator cylinders remain in the up position. If traveling more than 2 miles without testing, engage the mechanical locking tubes and "lower" the unit to secure them.

b. Upon completion of testing, remove the channel holding the sensors.

D. Precautions

1. Do not move the vehicle with the unit in the down position. A red light on the console indicates that the testing unit is too low to travel.

2. Before moving onto the traveled portion of the roadway, insure that all traveling safety is as required by the Traffic Engineering layout. Be sure that the required signs are in position and that all warning lights are functioning.

3. Read the Road Rater "Owners Manual Operations and Maintenance Guide" before operating the unit.

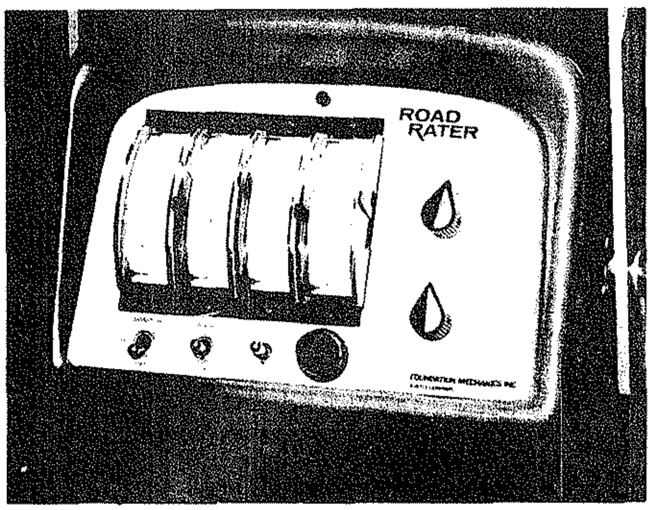


Figure 2

The control console of the Road Rater showing the selection controls and display meters.

OFFICE OF MATERIALS
ROAD RATER TESTS

SHEET NO. 79

1 COUNTY 2 HIGHWAY SYS. 4 ROUTE 5 BEGINNING MP 9 . ENDING MP 14 . DIRECTION 19

PAVEMENT TYPE 20 DATE TESTED 24 TIME 30 LAB NUMBER RR 35 – 36 YEAR BUILT 40

OBSERVER 42 WEATHER 59 64 SR 66 69 SR 71 74 SR 76

1	LOCATION 2	RANGE 8	READING SENSOR1 10	READING SENSOR2 12	REMARKS 14	LOCATION 18	RANGE 24	READING SENSOR1 26	READING SENSOR2 28	REMARKS 30	LOCATION 34	RANGE 40	READING SENSOR1 42	READING SENSOR2 44	REMARKS 46	77
2	.		.	.		.		.	.		.		.	.		0.1
2	.		.	.		.		.	.		.		.	.		0.2
2	.		.	.		.		.	.		.		.	.		0.3
2	.		.	.		.		.	.		.		.	.		0.4
2	.		.	.		.		.	.		.		.	.		0.5
2	.		.	.		.		.	.		.		.	.		0.6
2	.		.	.		.		.	.		.		.	.		0.7
2	.		.	.		.		.	.		.		.	.		0.8
2	.		.	.		.		.	.		.		.	.		0.9
2	.		.	.		.		.	.		.		.	.		1.0
2	.		.	.		.		.	.		.		.	.		1.1
2	.		.	.		.		.	.		.		.	.		1.2

REMARKS

STMP-SURFACE TEMPERATURE PINT-PRIMARY INTERSECTION SINT-SECONDARY INTERSECTION DINT-INTERSECTION W/DRIVEWAY XX-OTHER

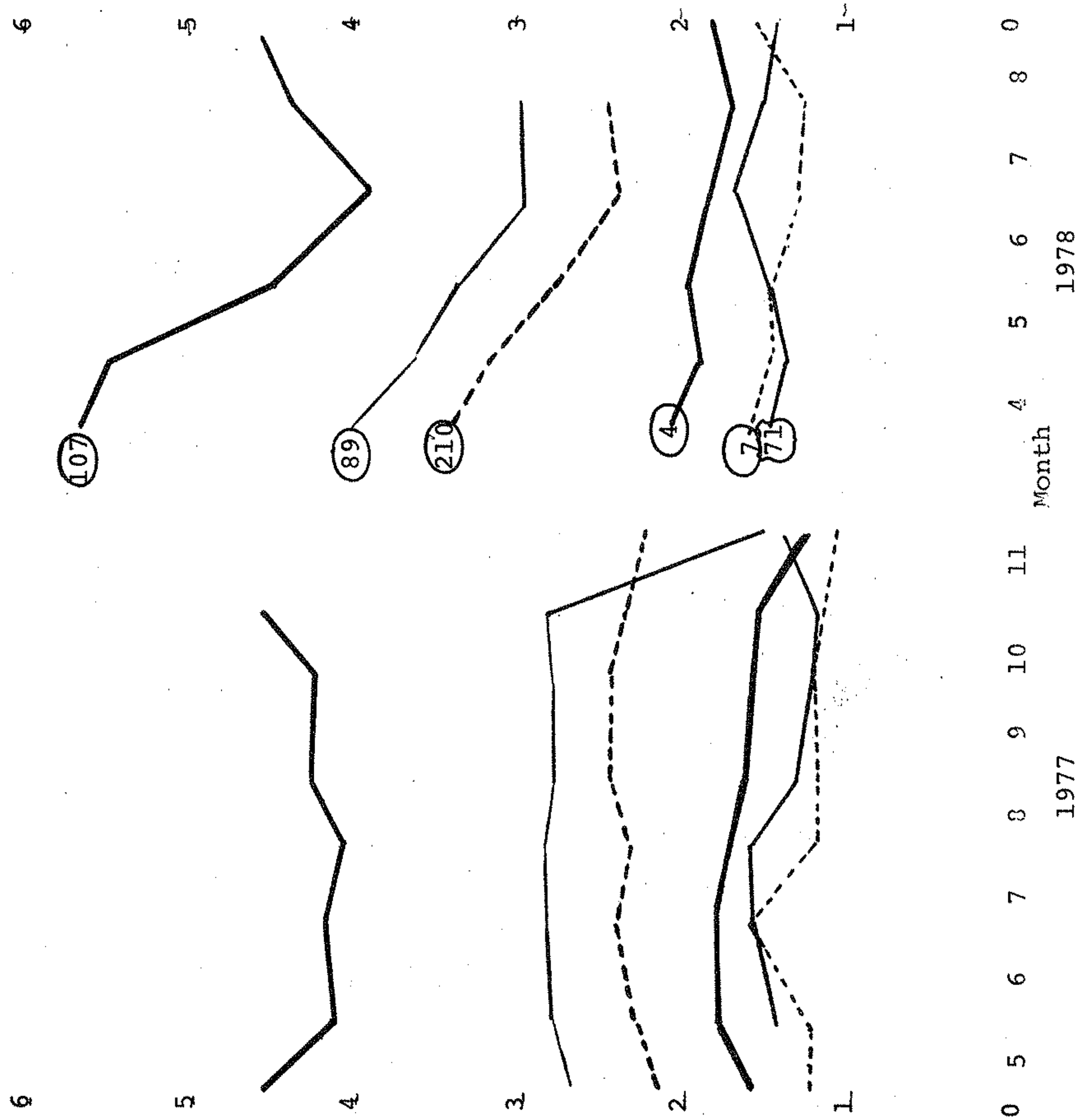
1	2	6	77
3			0.1
3			0.2
3			0.3
3			0.4

Appendix B

Seasonal Variation Trends From 1977-1978 Study Data

SEASONAL VARIATION

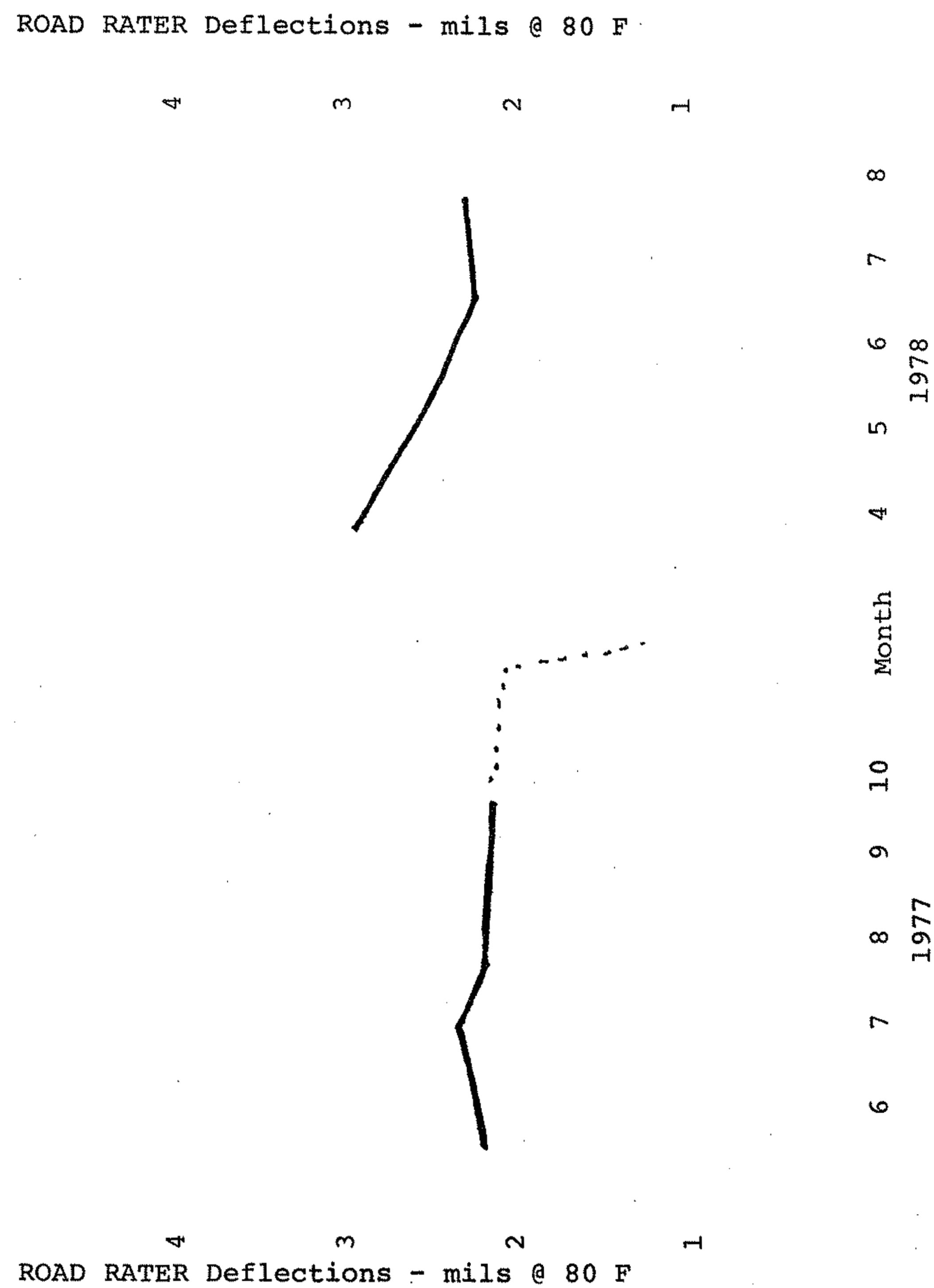
ROAD RATER Deflections - Mils @ 80F



ROAD RATER Deflections - mils @ 80F

SEASONAL VARIATION

Average of six projects



Appendix C

Table of Structural Ratings From 1978 Routine Testing

Flexible Primary Roads

Road	Location County	From	To	Road Rater Mils High	Low	Mean	△	SR Number
*4	Guthrie	0.75	10.15			1.74		4.30
8	Tama	0.51	7.70	4.30	2.10	3.23	0.52	3.00
13	Linn	0	3.61	1.80	0.84	1.10	0.23	6.42
16	Van Buren	7.15	10.35	3.60	1.04	2.32	0.68	4.22
16	Lee	45.52	59.10	3.90	1.04	2.79	0.60	2.62
20	Delaware	267.6	274.0	1.84	0.86	1.23	0.23	5.70
20	Delaware	275.5	282.5	2.40	0.50	1.24	0.48	6.18
20	Delaware	283.2	293.0	2.88	0.52	1.42	0.56	4.52
21	Tama	66.02	74.05	1.20	0.48	0.85	0.15	6.20
21	Black Hawk	74.06	82.0	1.68	0.70	1.05	0.22	5.42
22	Keokuk	0	10.11	6.20	2.34	3.92	0.73	2.28
22	Keokuk	15.36	22.80	5.80	2.34	3.76	1.15	2.66
22	Washington	22.80	28.11	5.40	2.80	3.77	0.58	2.65
22	Washington	28.86	35.06	4.80	1.92	3.22	0.68	3.20
22	Johnson	44.72	50.87	16.40	4.00	9.49	3.23	-
22	Muscatine	50.87	57.10	2.40	0.92	1.58	0.31	4.48
22	Muscatine	57.40	60.63	4.80	1.48	2.45	0.69	3.50
22	Muscatine	60.63	70.0	7.00	1.44	3.42	1.12	2.50
23	Wapello	1.81	14.48	3.70	1.28	2.40	0.52	2.90
25	Union	37.46	48.00	3.20	1.68	2.24	0.39	3.20
25	Adair	49.00	56.75	2.94	1.16	1.97	0.38	3.75
25	Adair	59.00	70.00	3.20	1.32	1.87	0.37	3.80
31	Woodbury	0.29	4.19	4.40	1.24	3.04	0.92	3.30
31	Woodbury	5.06	11.76	4.90	1.20	2.97	0.79	3.44
31	Woodbury	12.86	20.07	4.50	1.28	3.06	0.76	3.26
31	Woodbury	20.8	27.5	4.90	1.64	2.76	0.83	3.52
31	Cherokee	27.71	38.67	4.60	1.44	2.80	0.64	2.88
37	Monona	10.22	22.00	5.60	2.58	3.88	0.75	2.50
37	Shelby	23.91	36.17	4.20	1.08	2.66	0.77	4.20
38	Cedar	18.86	25.43	2.76	0.94	1.78	0.45	4.45
48	Montgomery	24.00	42.00	2.52	0.80	1.60	0.38	4.30
48	Cass	43.04	48.49	2.34	0.94	1.43	0.27	5.25
49	Adams	21.37	27.81	3.50	1.28	2.46	0.49	3.50
54	Floyd	0.5	2.99	7.60	1.48	4.17	1.13	1.80
59	Pottawattamie	39.5	49.0	2.40	1.20	1.72	0.30	4.98
61	Jackson	159.64	168.90	1.84	0.54	1.09	0.35	5.48
61	Jackson	168.90	174.70	1.60	0.72	1.20	0.18	5.22
62	Jackson	1.00	6.10	3.40	0.86	1.92	0.55	3.80
71	Montgomery	30.00	47.00	3.20	0.62	1.67	0.52	4.10
*71	Cass	49.00	58.31			1.44		4.90
88	Lee	0.56	8.01	6.00	1.68	4.00	1.10	2.50
*189	Boone	1.97	6.80			2.91		2.70
91	Kossuth	0.47	4.18	7.40	3.60	5.54	0.89	-
96	Tama	10.07	16.79	3.30	0.94	2.25	0.57	4.40
97	Lucas	0.0	0.91	7.60	2.70	5.70	1.26	0.65
99	Des Moines	12.90	19.79	4.70	1.86	3.24	0.59	3.20
101	Benton	1.53	15.75	4.40	0.78	2.30	0.68	4.00
103	Lee	0.0	5.71	6.80	3.30	4.67	0.87	1.50
*107	Franklin	4.32	11.37			4.32		1.45
107	Cerro Gordo	12.20	17.45	4.30	2.22	3.24	0.45	2.48
110	Buena Vista	2.06	14.25	4.90	1.98	3.30	0.65	3.00

Road	Location County	From	To	Road Rater Mils High	Low	Mean	△	SR Number
112	Clayton	0.38	5.19	8.60	2.40	4.10	1.30	1.50
118	Hardin	0	3.70	6.00	2.80	4.51	0.82	1.58
136	Jones	47.2	52.8	3.60	1.40	1.96	0.55	4.80
136	Jones	54.5	57.4	5.00	1.98	3.30	0.73	2.88
136	Jones	58.1	64.0	4.60	1.20	2.54	0.79	3.85
136	Jones	65.0	72.0	3.70	1.24	2.35	0.61	4.08
136	Dubuque	73.2	80.7	4.80	1.36	2.59	0.64	3.60
136	Dubuque	82.3	87.0	3.60	1.16	2.45	0.71	3.90
136	Dubuque	88.94	97.05	4.50	0.62	2.57	0.89	2.85
139	Howard	0.5	11.24	3.90	0.84	2.55	0.60	3.55
144	Boone	1.70	6.61	3.90	1.40	2.83	0.67	4.50
144	Greene	10.2	16.45	7.40	3.40	5.12	0.93	1.08
144	Greene	17.49	22.0	5.20	2.46	3.54	0.73	2.40
144	Greene	22.5	29.34	3.80	1.86	2.72	0.45	3.45
145	Fremont	0.42	4.32	13.20	3.30	7.03	2.23	0.60
146	Poweshiek	18.04	20.94	3.50	1.12	2.13	0.65	3.70
148	Taylor	8.49	14.46	2.34	1.08	1.50	0.31	4.96
148	Taylor	14.46	29.10	4.70	1.36	3.17	0.98	3.04
148	Adams	35.1	50.0	2.70	1.56	2.11	0.34	4.46
175	Monona	0	4.57	4.50	0.54	2.64	1.04	3.06
175	Calhoun	105	111.50	4.20	1.92	2.97	0.57	3.15
175	Webster	111.5	119.5	4.50	1.24	2.91	0.71	3.20
175	Hamilton	138.72	144.83	3.20	1.64	2.46	0.47	3.50
175	Hamilton	145.61	153.65	3.50	1.52	2.33	0.49	3.65
*175	Hamilton	159.46	165.67			2.00		3.90
175	Hardin	166	172.4	2.64	1.24	2.15	0.31	3.85
187	Buchanan	0	12.14	4.00	1.98	2.84	0.51	2.42
188	Butler	3.08	13.26	6.60	1.86	3.69	1.08	2.55
188	Bremer	14.20	24.28	4.80	1.16	2.75	0.76	3.60
193	Fayette	0	8.67	6.00	1.12	3.49	1.13	2.75
196	Sac	0	7.81	4.50	1.24	2.70	0.83	3.80
198	Benton	0	2.67	3.10	1.36	2.21	0.49	4.00
200	Benton	0	2.16	2.70	1.80	2.27	0.24	4.45
207	Warren	0	2.73	6.80	2.46	3.86	1.02	2.80
*210	Story	0.86	4.6			2.44		3.30
210	Story	4.7	8.1	4.20	2.10	3.16	0.53	3.20
210	Story	8.4	15.0	5.00	2.04	3.35	0.74	2.98
221	Story	0	5.58	6.00	2.10	3.85	1.04	1.70
226	Kossuth	0	10.36	4.60	2.46	3.40	0.47	2.50
227	Mitchell	0	5.09	2.90	1.16	1.86	0.47	4.20
229	Tama	0.49	5.41	5.80	2.16	4.02	0.98	2.05
233	Marshall	0.63	5.30	3.50	1.48	2.30	0.46	3.40
243	Woodbury	0	7.58	2.76	1.20	1.90	0.41	4.50
251	Madison	0	1.24	4.20	1.76	3.01	0.61	3.60
254	Winnebago	0	7.91	3.70	1.68	2.72	0.52	3.70
255	Mitchell	0.36	2.26	9.00	2.58	5.51	1.64	0.62
262	Wright	0	1.29	16.00	5.20	9.06	2.88	-
273	Davis	0	10.0	16.40	4.40	7.05	2.32	0.55
279	Benton	0	2.40	12.80	2.82	4.85	2.36	1.40
282	Buchanan	0.64	5.28	4.20	1.16	1.96	0.58	3.70
284	Buchanan	0.45	5.44	4.70	1.98	3.06	0.70	2.30

Flexible Primary Roads

-1c

Road	Location County	From	To	Road Rater Mils High	Low	Mean	△	SR Number
286	Carroll	0	9.24	4.80	1.62	3.15	0.78	2.95
294	Decatur	0	6.0	3.70	1.68	2.36	0.51	3.80
296	Fayette	0.64	4.59	4.60	1.80	2.97	0.65	2.90
297	Black Hawk	0.58	3.34	4.30	1.92	2.88	0.56	3.10
303	Jefferson	0.34	3.51	12.00	2.70	7.14	2.24	0.35
312	Mitchell	0.0	4.93	5.80	1.86	3.34	1.03	2.55
325	Winneshiek	0.47	4.08	2.52	1.32	1.99	0.26	4.40
326	Butler	0	1.5	8.00	2.30	4.69	1.39	1.70
358	Kossuth	0	1.1	8.40	3.30	4.86	1.01	1.50
364	Allamakee	0	6.01	4.70	1.20	2.42	0.73	3.00
374	Clay	0	7.55	2.64	1.04	1.80	0.47	4.05
393	Chickasaw	0.63	2.40	3.40	2.50	2.88	0.26	3.50
400	Madison	0.63	4.06	3.60	2.10	2.85	0.40	3.90
I-80	Adair	74.0	85.5	1.60	0.66	1.01	0.26	6.55
I-80	Adair	86.0	99.0	1.44	0.60	0.94	0.19	6.80
I-80	Jasper	174.0	180.4	1.88	0.86	1.28	0.28	6.35
I-80	Johnson	226.0	239.5	1.24	0.40	0.64	0.15	7.10
I-80	Cedar	257.7	264.65	1.40	0.42	0.78	0.21	6.90
I-35	Clarke	32.96	42.88	1.32	0.40	0.84	0.21	6.10

* Seasonal Variation Road-Average of Many tests in 1977 and 1978

Road	Location County	From	To	Road Rater Mils High	Low	$\bar{X}$	$\triangle$	SR Number
X-40	Cedar	Mechanics-ville	South	5.00	1.80	3.73	0.97	2.20
S-43	Franklin	Chapin	Sheffield	9.40	2.40	4.87	1.30	1.50
J-10	Fremont	Bartlett	Tabor	6.20	2.90	4.81	0.78	1.85
J-34	Fremont	Percival	Sidney	8.60	2.04	5.91	1.41	1.10
J-64	Fremont	U.S.275	U,S. 59	3.30	1.52	2.13	0.41	3.50
L-58	O'Brien	Osceola Co.	South	5.40	2.04	4.18	0.70	2.38
M-12	O'Brien	Osceola Co	South	4.70	2.58	3.47	0.48	4.10
M-12	Osceola	O'Brien Co	North	5.80	3.20	4.57	0.56	2.00
A-48	Osceola	Melvin	M-12	14.80	5.60	8.06	2.06	-
L-58	Osceola	O'Brien Co	North	5.60	3.40	4.22	0.51	2.30
L-40	Osceola	O'Brien Co	North	8.40	4.70	6.17	0.92	0.70